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LONG-TERM PLANNING OF ENERGY ECONOMY FOR LESS DEVELOPED AREAS

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Statistical investigation of national income and of energy consumption

/1/ Experts active in the field of energy supply have long since endeavoured to find a relationship between the energy consumption and the per capita national income, the latter being the most important measure of the welfare of a country. Knowledge of this relationship will permit to establish the efforts worth making in the individual countries to secure the energy supply on the one hand, and to determine the quantities of energy required to attain a planned increase in the national income, on the other. Searching for the relationships between the various index numbers characterizing the national economy and the consumption of energy is a significant aid for the long-range planning of energy supply. However, considerable care must be taken when making use of such deduced relationships since - as to be proved later on - the special features of the individual areas may considerably modify the conclusions drawn on the whole.

/2/ The relationship between per capita national income and per capita energy consumption was established by Mason[1] among others. In accordance with the data compiled by this author, Fig.I. shows the relationship mentioned above in reference to the less developed countries. The correlation of the two variables is distinctly recognizable in the

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1 Mason, E.S., Energy Requirements and Economic Growth. International Conference for the Peaceful Uses of Atomic Energy, held at Geneva, August 1955. Doc.P/802/1955/.

figure in spite of the considerable scattering next to the approximating straight line.

/3/ The investigation of the correlation between energy consumption and national income is cumbersome if effected by the method mentioned above, This is partly due to the uncertainty of the available information. When submitting data covering energy requirements, the method of numerically converting energy of higher value /e.g. electrical power/ into other forms of energy is subject to discussions and the scope of national income is not unequivocally established /e.g. whether it covers household work/. Conversion to a common rate of exchange constitutes another source of uncertainty.

/4/ Index numbers supplying information on the increase of energy requirements rather than on their absolute value are more serviceable for the establishment of long-range energy requirements. Within each country, there exists a close connexion between the annual rate of growth of per capita national income and the variations in per capita energy consumption. This is demonstrated e.g. in Fig.II. where, according to Ghaussy[2], the variations in the index numbers of the two specific ratios mentioned above are shown for France, from 1920 to 1956; the closeness of the correlation is clearly presented by the similarity in the shape of both graphs. Energy consumption traces even the minor fluctuations of national income.

/5/ The idea may be raised to make inferences concerning the prospective development of less developed countries from the earlier development of more developed countries. This, however, is mostly impracticable since the less developed countries do not, to-day, have to solve the problems of their energy supply by means of the old-type equipments, obsolete from the present engineering point of view. The conditions of development therefore, differ, considerably. Furthermore, the possibilities of comparison are greatly disturbed by the relapses /due to wars, economic crises, natural catastrophes/ that have occurred in the development of the industrially developed countries.

/6/ For illustrating the conditions of development, a comparison of the simultaneously occuring data of various countries may be chosen. Utilizing the data contained in the 1961 Statistical Yearbook of UNO, we have carried out calculations to establish relationships between the increases in energy requirements and those in national income by comparing various countries rather than within a single country.

/7/ In Table 1, four indexes are listed for each country - based upon data supplied by UNO[3] - for which correlations are sought for by the rules of mathematical statistics:

X_1 - Average annual increase of per capita income from 1957 to 1960, %;

X_2 - Proportion of the 1958 national income derived from agriculture, forestry and fishery %;

X_3 - Per capita energy consumption in 1960, kg of coal equivalent;

Y - Average annual increase of per capita energy consumption from 1957 to 1960, %.

/8/ First, let the direct correlation between the annual increase of per capita national income /X_1/ and the annual increase

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2 Ghaussy, A.G., Die Rolle des Energiesektors in der Entwicklungspolitik. Westdeutscher Verlag, Köln und Opladen /1960/, p.40.

3 Statistical Yearbook 1961. United Nations, New York /1961/.

of per capita energy consumption /Y/ be investigated. The percentual variations are shown in Fig.III. It can be seen that hardly any relationship exists between the two indexes: the coefficient of correlation - according to our calculations - is 0.24. The slope of the regression line is rather small. The slackness of correlation is due to the fact that, besides the influence of variations in the national income, other factors also effect considerably the increase of energy consumption.

/9/ It stands to reason that the rate of growth of energy consumption is affected by the distribution of the increase in national income among the contributing branches of national economy, that is by the fact, whether the increase originates in industry with a high energy consumption or in agriculture with a low energy consumption. Let a further variable be included in the computations, that which indicates the percentual proportion of agriculture, forestry and fishery in the absolute value of the national income /Table 1,X_2/. Instead, the use of a characteristic indicating the proportion of the branches mentioned above in the increase of national income /and not in its absolute value/ would, of course, have been more practicable, the relevant data, however, are rather incomplete.

/10/ The calculations have shown that the introduction of this new variable has tightened the correlation considerably, the correlation coefficient increasing from 0.24 to 0.51. The correlation however, cannot yet be regarded as close. The significant increase in correlation also indicates that energy consumption depends, to a much higher extent, upon this new variable, as shown clearly in Fig.IV. The regression line is much steeper in this figure.

/11/ An attempt has been made to introduce yet another variable, the absolute value of per capita energy consumption /Table 1,X_3/. The effect of this new variable is not significant, its introduction increases the correlation coefficient but slightly, from 0.51 to 0.52.

/12/ In Figs.III. and IV. the regression lines are shown as functions of two variables /X_1, X_2/. Accordingly, the per capita increase in energy consumption may approximately be obtained, by means of the following equation:

$$Y = 0.227\ X_1 - 0.194\ X_2 - 3.86.$$

/13/ As observable in Figs.III. and IV. there are considerable deviations in respect to the regression lines due to causes not taken into consideration. The correlation of the indexes taken into account is, therefore, weak even if demonstrably present. Certain inferences, however may still be made from the investigations and approximate figures can be obtained for long-range energy production. It can be primarily established in this manner that in less developed countries, largely, a 3.5% increase of energy requirements corresponds to a 2.1% increase in the national income. However, in consideration of the fact that energy requirements undergo an increase on account of technical developments /approx. 2.5% annually/ even when the per capita national income does not grow, every percent change in the national income will imply on the average only a 0.4% change in energy requirements /see regression line in Fig.III/. If, besides the planned increase in national income, the percentage of the national income originating from agriculture, forestry and fishery is also given, the prospective increase in energy may be calculated by this formula. For instance, should the national income grow by 3% in a country where 40% of the national income is yielded by agriculture, the prospective increase in energy consumption will amount to 4.6%.

/14/ These computation methods are, in general, too inaccurate to permit the direct utilization of their results in the long-range planning of energy requirements. Energy requirement estimations of such character may be used as a basis, only if detailed data on the economic development of the area subject to investigation are not available. The methods mentioned above are suitable for the preparation of planning, for a crude characterization of perspective conditions, rather than for planning itself.

Methods for determining long-range energy requirements

/15/ The factors determining the long-range plans of energy supply are the long-range objects of economic development, for whose realization power and fuel economy are indispensable means. It is obvious, however, that the actual possibilities of energy supply must be taken into consideration when setting long-range aims /national income, industrialization, employment, living standard, etc./.

/16/ This implies, for the purpose of practical planning, that the qualitative and quantitative distribution of energy sources to be made available to national economy must be determined on the basis of the theoretical energy requirements - from the quantitative and qualitative distribution of the necessary forms of energies - needed for realizing the aims of long-range economic development, with due regard to the technical possibilities and the costs of energy supply.

/17/ The necessary forms of energy are qualitatively determined by the objects of utilization specified in conformity with the individual components of the national income. The most important forms of energy, from the viewpoint of quantity, are heat, mechanical energy and chemical energy. Several energy sources are available to satisfy the demand for the various forms of energy.

/18/ The qualitative dissimilarities of the energy requirements, as described above, make it necessary to investigate energy requirements both summarily and separately, according to the forms of energy. In order to consider summarily the various energy forms - convertible into each other - and energy sources, there is need for a common unit of measurement, such as the calorie or the kWh. The theoretical and practical problems of the conversion of units of measurement are dealt with in detail by LAADING[4].

/19/ The methods employed to determine energy requirements may be classified into two main groups. To the first group belong the so-called global methods of estimation, generally used for the summarized estimation of the total energy requirements and - practicably - for estimating the requirements in respect to a certain form of energy source /primarily to electric power/. The methods described under /2/ and /13/ also belong under this heading. According to experiences in Hungary, it is desirable to deal separately at least with the requirements for heat and for mechanical energy /electric power/ when making global estimations of the total energy requirements. A basis of global estimation may be obtained by extrapolating to the future a known trend of energy consumption of a past period, or the

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4 LAADING,K.F.,Methods for Establishing Overall Energy Balance Sheets. World Power Conference, I A1/8.Madrid /1960./

future development of a series of data referring to economic development /national income, volume of industrial production, etc./ as a function of which the prospective energy requirements can be calculated on the basis of similar relations in the past. Knowledge of the statistical data referring to the bygone period is an indispensable precondition in either case.

/20/ With the so-called synthetic method of calculation, the prospective requirements are determined separately for each of the branches of national economy, making allowance for the prescribed or prospective long-range tasks in the individual branches.

In industry, the growth of production must be considered, separately investigating the development of the various branches of industry, that of energy-intensive products /metallurgical and chemical products, building materials, products of the light and food industries,etc./ and the prospective development of specific energy consumption per unit product. Specific energy consumption primarily depends upon the technology of production, upon the engineering level of production, upon the chosen energy source.[5]

/21/ In the field of transport, the prospective energy requirements can be computed on the basis of the envisaged tasks of transport. Railway, highway, water and air transports must be separately investigated and the energy requirements both of passenger and goods transports must be examined separately for each of the above. The energy requirements of agriculture constitute a relatively small proportion of the national energy requirements; depending primarily upon the degree of mechanization of agriculture, they present themselves mainly in motor fuels and electric power. The heat requirements of agriculture are relatively low /drying,etc./. Household and communal energy requirements can be calculated by analyzing the energy consumption per inhabitant or - for higher accuracy - per household /home/. A considerable proportion of this energy may consist of energy used for heating, depending upon the geographical situation and weather conditions of the given area.

/22/ A precondition for applying either of the methods outlined above is the knowledge of statistical data characteristic of the energy consumption of the given area. The reliability of planning greatly depends upon the accuracy and detailedness of the statistical data.

/23/ Which to choose of the global or synthetic methods depends upon the detailedness of the plans for the economic development of the given area. With detailed plans available, application of the synthetic method, based upon fundamental data in greater detail, will be the more practicable.

/24/ It is advisable to use the global method of estimation even when fundamental data are available in necessary detail for calculation by the synthetic method. This offers the possibility - according to experiences gained in Hungary - to check the results obtained by the sythetic method.

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5 A serviceable aid to planning are the data collections containing data on specific energy consumption, e.g.:
Scholl,W.,Mackethun,W.,Masukowitz,N., Anhaltszahlen über den Elektrizitäts-, Kraft- und Wärmebedarf der Industrie. VDEW, Frankfurt a.M./1951/.
Ringbuch der Energiewirtschaft, Frankfurt a.M./Continually since 1952, on loose leaves/.
Anhaltszahlen für die Wärmewirtschaft in Eisenhüttenwerken. 5.neubearb.Aufl. Verlag Stahleisen, Düsseldorf /1957/.
Wärmeverbrauch in Industrie und Haushalt. VDI-Verlag,Düsseldorf /1959/.

/25/ A sound basis for calculating long-range energy requirements may be gained by the analysis of the data of a country or area that had previously undergone economic development of a similar character.It is advisable,'in this respect, to compare primarily such areas whose natural resources and climatic conditions resemble, on the condition that the difficulties outlined under /5/ do not prevail.

/26/ On the base of the energy requirements determined by the global or synthetic method, the energy supply required for producing the national income can be elaborated in a number of variants since the energy sources suitable for supplying the individual forms of energy /heat,mechanical energy, chemical energy/ can be substituted for each other within certain technical limits. The task lies in determing the variant ensuring an optimal energy supply from among the numerous possible combinations of energy sources.

/27/ When establishing the provisions to be made for the development of national economy /national income, volume of industrial production, etc./, taken as a basis for determining the energy requirements, the optimal variant of energy supply - determined as described above - and the effect of this variant upon foreign trade, industrial production, transport, etc. cannot yet be known. Consequently, after the conclusion of the calculations, it must be checked whether the optimal variant of energy supply can be brought in harmony with the originally set aims of economic development; otherwise, provisions must be made to co-ordinate the individual tasks of development.

/28/ One of the most important requirements in the development of less developed countries is the fast and vigorous increasing of labour productivity. The fundamental means to achieve this aim is to mechanize production, i.e. the substitution of human /and animal/ effort by mechanical work, and then extending the application of the latter. In present technical practice, the utilization of mechanical energy commonly implies the use of electric power, that is electrification, if transport is disregarded.

/29/ The mechanical energy demanded by transport will presumably be supplied by oil products /petrol, gas oil, diesel oil/, but electric railway traction may also be taken into account.

/30/ Worthy of consideration under the special circumstances of certain areas are the utilization of wind power and of digester gas, the latter obtained by the gasification of agricultural wastes.[6]

/31/ A fundamental question in electrification is the choice of the primary energy sources /fuels, water power and, perspectively, nuclear fuels/. A special task of electrical-power economy consists of satisfying load requirements, especially peak loads.The determination of long-range energy requirements must, therefore, be completed by determining the peak load. An adequate basis for solving this question is offered by planning the energy requirements.

/32/ For covering heat energy requirements, fuels are to be considered primarily, however, the perspective possibilities of directly

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6 Gádor,E., Local Sources of Energy, Micro-hydroelectric Stations, with particular Emphasis on the Electrification of Agriculture. Section A.4.3.3 of this Conference.

utilizing solar radiation - especially for countries in the tropics and subtropics - must also kept in mind. Characteristic of numerous less developed countries is the large-scale utilization of vegetal and animal fuels; efforts must be made to substitute mineral fuels for fuel wood and for valuable manure, destined to play an important role in the development of agriculture.

/33/ Fundamentally, there are two circumstances that determine, from the economic point of wiew, the practicable energy sources and their quantitative ratios for producing determined forms of energy in a given case: the prices of the energy sources and the investment and operational costs entailed by their use on the one hand, and the utility of the energy sources related to their technical applicability, on the other.

/34/ As to the costs of energy supply, the costs of the energy sources are not the only point. Not only energy sources are needed to supply the consumers with energy, but also energy conversion and distribution equipment on the one hand, and consuming equipment, directly utilizing energy in the final stage, on the other. Figuring among the costs of energy supply are the total costs of energy conversion, distribution and utilization as well.

/35/ Energy sources suitable for similar consumer purposes /e.g. for firing in boilers/ cannot, however, be utilized with identical effectiveness; this difference in effectiveness is independent of the ratio of the purchase costs. In order to determine the utility - differing for each area of utilization - of energy sources, the technical characteristics, operating and depreciation costs of the energy consuming equipments must be taken into account.[7]

Economic considerations on the establishment of energy-producing, converting, distributing and consuming equipment

/36/ Energy consumption is a close function of the economic structure of any country. In the energy-consuming branches of industry, energy figures as a basic material; the purpose of the energy-producing, converting and distributing branches of industry, however, is the most economical satisfaction of energy requirements.

/37/ Energy production, conversion and distribution demand high capital investments. Table 2 lists the relative values of specific requirements for fixed capital in the individual branches of energetics, including the dependent requirements for fixed capital in the allied branches, founded upon data obtained in Hungary. Thus, for instance, the capital investments made in mining, conforming to the coal requirements, figure among the data of electric-power generation.

/38/ Except petroleum refining, the branches playing a role in energy supply require higher capital investments than the average industrial production. This primarily refers to electric-power generation and gas production.

/39/ The share of the energy-producing branches of industry in the total of capital investments of a country depends upon the structure

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7 Sóváry,E., Bewertung der Energieträger.II.Konferenz für industrielle Energiewirtschaft, Budapest, den 16-21.Oktober 1961.Energiagazdálkodási Tudományos Egyesület, Budapest /1961/.

of industry. In 1954[8], about 18 % of the total investments of the European countries were investments in the energy sector and this share tends to increase. Besides the greater rate of development in the branches of industry with high energy consumption, this growth is due to the fact that energy production, and mainly coal production, demands ever increasing investments of capital owing to the decrease of coal supplies.

/40/ In view of the high requirements for capital investments in energy supply, the co-ordination of this development with the development and energy requirements of the other branches of industry and of national economy is of high importance. Disproportionate development may give rise to grave difficulties in the economic life of a country. Backwardness in the supply of energy may entail the introduction of compulsory restrictions in certain sections of consumers, primarily in industry, causing heavy losses on account of the lack of exploitation of consumer equipment. Overdevelopment of the energy supply, on the other hand, results in a superflous immobilization of capital. The excessive lenght of the periods of capital investment in important energetic developments /about 3 years for power stations, 5-8 years for mines/ constitutes another drawback owing to which long-term plans cannot be modified at short notice. The acceleration of capital investments is a task of special difficulty nor is their postponement an easy one since the suspending of already commenced investments may cause heavy economic damages by losing the interest of the capital invested.

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8 Europe's Growing Needs of Energy. OEEC, Paris /1956/.

Table 1.

Statistical data characteristic of national income and of energy consumption

Country	Avg. annual increase of per capita national income 1957-1960 X_1 %	Proportion of agriculture, forestry and fishery in national income 1958 X_2 %	Per capita energy consumption 1960 X_3 kg	Avg. annual increase of per capita energy consumption 1957-1960 Y %
Brazil	4.2	26	372	7.1
Burma	2.4	41	55	10.3
Chile	1.0	14	883	1.7
Cyprus	-5.2	23	829	-4.5
Equador	1.2	36	177	5.7
Malaya	3.9	46	241	0.6
Korea	1.8	41	254	13.7
Pakistan	0.6	54	505	8.8
Paraguay	3.4	45	355	6.2
Philippines	-1.5	33	138	2.3
Rhodesia and Nyasaland	3.0	20	522	-2.6
Thailand	-1.3	38	63	5.9
Jamaica	5.0[a]	31	-528	6.5[a]
Malta	3.8[a]	8	449	-3.2[a]
Cambodja	-0.4[a]	47	31	7.2[a]
Columbia	10.4[a]	37	480	1.7[a]
Congo	-2.7[a]	26	81	-10.8[a]
India	3.6[a]	50	138	4.2[a]
Indonesia	6.8[a]	60	135	4.3[a]
Average	2.11	35.6	310.3	3.54

[a] 1957-1959

Table 2.

Total indirect and direct requirements for fixed capital in Hungary, belonging to identical production values in the individual branches of energetics. /The average requirements for fixed capital in industrial production = 1,0/

Electric-power generation	3.0
Town gas production	2.3
Petroleum and natural gas production	1.8
Peat mining	1.5
Coal mining	1.4
Briquetting	1.2
Petroleum refining	0.6

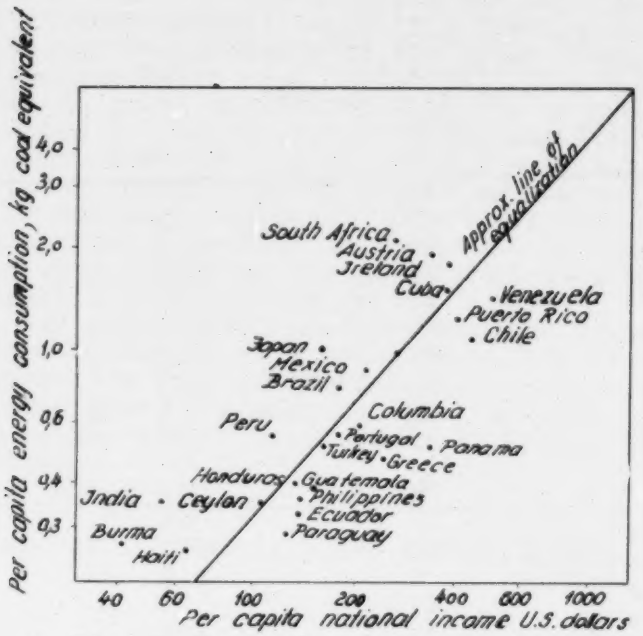

Fig. I National income vs. energy consumption

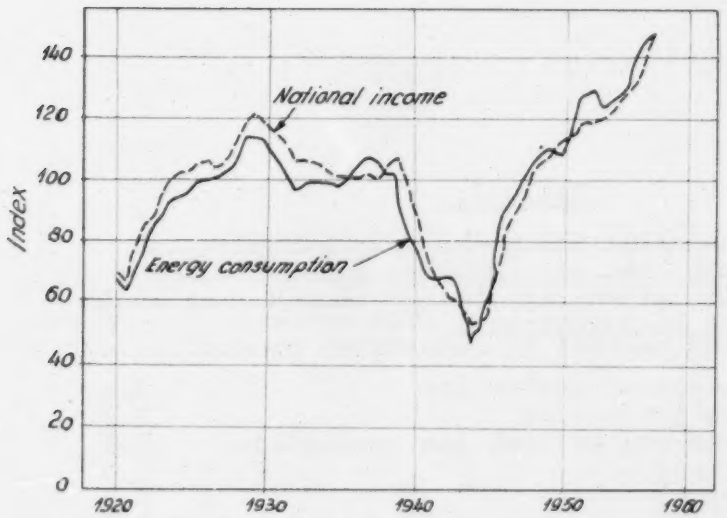

Fig. II Variations in the indexes on national income and energy consumption in France

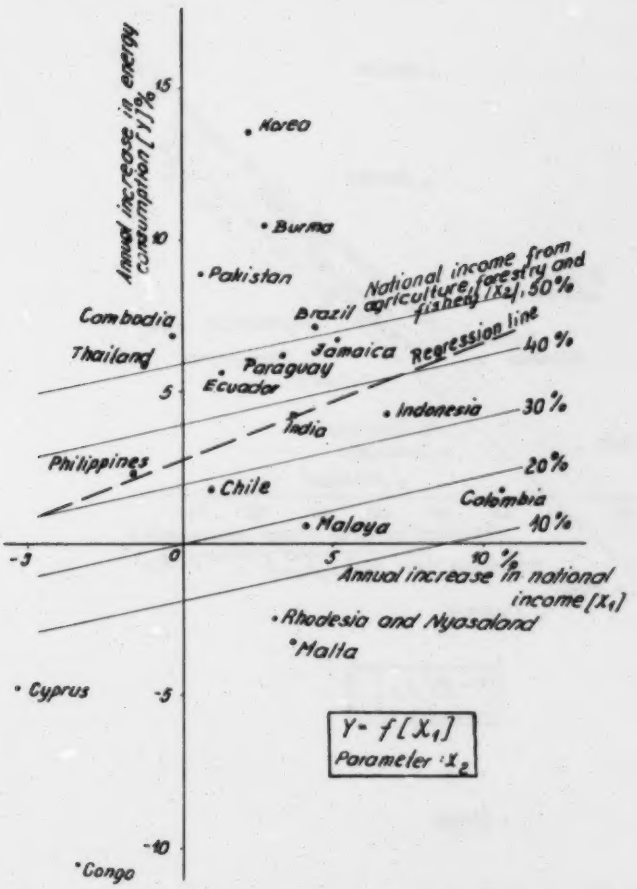

Fig. III Annual increase in energy consumption vs. annual increase in national income

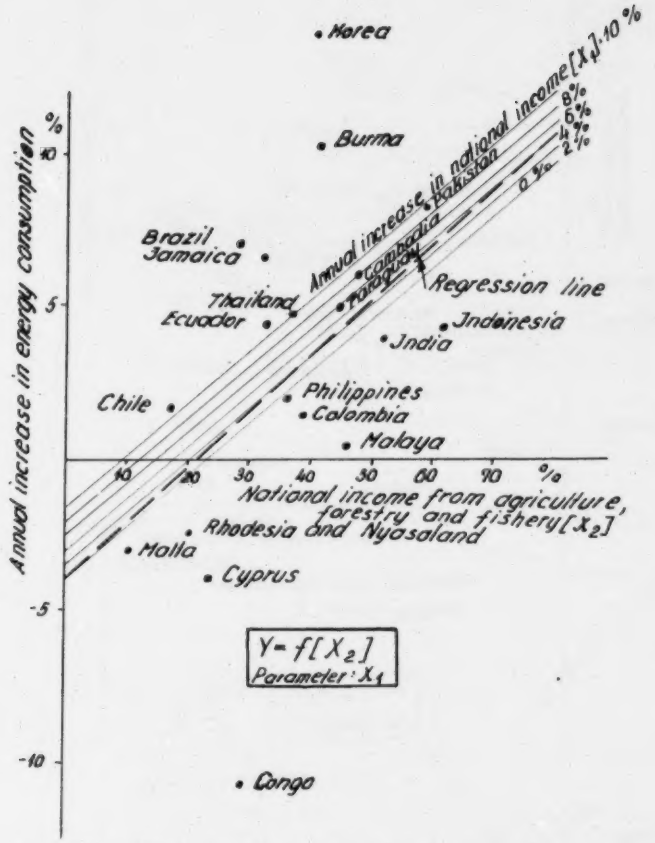

Fig.IV Annual increase in energy consumption vs. relative share of agriculture in the national income

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